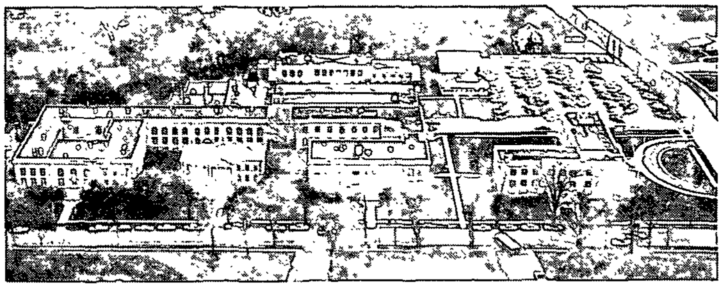

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# THE DEVELOPMENT OF A DOUBLE ELEMENT, PULSE ECHO, PVDF TRANSDUCER

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**The Development of a Double Element, Pulse Echo, PVDF Transducer**

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# THE DEVELOPMENT OF A DOUBLE ELEMENT, PULSE ECHO, PVDF TRANSDUCER

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## ABSTRACT

This paper presents a simple way to use PVDF piezoelectric films to construct a multiple active element ultrasonic transducer. With this transducer, pulse echo measurements can be made using a separate transmitter and receiver. This eliminates the need for special electrical circuitry and provides the opportunity for individual design of receiver and transmitter response characteristics.

## INTRODUCTION

Pulse echo techniques are widely used for ultrasonic inspection of materials.[1] Standard pulse echo techniques require the use of a single transducer for generation and detection of acoustic signals. In a typical application, the transducer is first coupled to the test object. The transducer is electrically pulsed, and an acoustic disturbance propagates into the test object. A signal, reflected back from an interface, produces a secondary signal in the transducer. Finally, the test object is characterized by analyzing the echo signal.

A limitation of the use of the same transducer for transmission and reception is that supplementary electrical circuitry must be introduced. In a straightforward employment, the excitation pulse is applied directly to the echo signal amplifier. Either the amplifier must be switched out of the circuitry during pulsing, or it must be designed to withstand high input voltages and recover quickly from saturation. If the pulse drive circuitry is not switched out during echo reception, the input impedance of the amplifier should be lower than the drive circuitry to achieve efficient signal transfer.

Another drawback of the standard approach is that the transducer design must be a compromise between optimum transmitter and receiver characteristics. The piezoelectric element should both withstand large electric fields and be very sensitive. Different piezoelectric materials cannot be selected for transmission and reception, and the receiving and transmitting elements cannot employ different geometries.

One way to circumvent the difficulties of single transducer, pulse echo measurements is to simply place two active elements in the same housing. If standard ceramic piezoelectric materials were used, the construction could be bulky and cumbersome, and multiple reflections between elements could interfere with the echo signals. However, multiple element transducers are practical when polyvinylidene fluoride (PVDF or Kynar) plastic piezoelectric films are the active elements. Since they are thin films, a compact construction is easily achieved, and their natural broad band response allows straightforward suppression of internal reflections.

The double active element transducer design would be particularly useful in Barker-coded sequence, multilayer transducers.[2] The Barker code sequence of two multilayer elements could be opposite, allowing for straightforward pulse compression in single transducer pulse echo measurements.

## TRANSDUCER CONSTRUCTION

The transducer described below has two PVDF elements. When used for pulse echo work, the need for special circuitry is precluded since there is a separate transmitter and receiver within the same assembly. Although the transmitter and receiver elements are identical in this particular construction, different geometries could easily have been employed.

Figure 1 is a mechanical drawing of the transducer. The plastic piezoelectric elements are 110 μm thick PVDF copolymer films (VF2-VF3 from Pennwalt Corp.). Each element is a laminate of two films of opposite polarity. Electrical connection is made to the element center and the surfaces are grounded. This provides effective electrical shielding between elements and from the environment. The bottom side of the inner element is bonded to a disk of unpolarized Kynar. This provides a good impedance match with the film, thereby reducing backside reflections and producing broad band performance. The top side of the inner element is bonded to a short Kynar disk which, on its opposite end, is attached to the outer element. The Kynar provides an excellent impedance match to the films, and is an effective attenuator of ultrasound (loss tangent ≈ 0.08 at 1 MHz). This means that echos from reflections between the elements rapidly disappear. The top of the outer element is connected to a polystyrene delay line. The polystyrene acts as a low loss, impedance matching layer between the PVDF films and the neoprene front-face. The neoprene is used to couple energy into solid samples without the use of viscous fluids or bonding agents.

Figure 1 here

The assembly procedures for a similar, but single element, transducer are described elsewhere.[3] The rationale behind using soft neoprene to couple ultrasound into solids is also discussed in this paper.

## TRANSDUCER PERFORMANCE

The operation of the transducer is presented below in the form of a series of oscilloscope traces of the signal received at the inner transducer resulting from a single-cycle 1.5 MHz pulse at the outer transducer. Figure 2 is a trace recorded during construction, before bonding of the neoprene front face to the polystyrene delay line. The very first signal is radio frequency communication between the two elements. Note that it is of lesser amplitude than some of the acoustic signals coming later, and it by no means causes amplifier saturation problems. The strong second signal comes from the acoustic wave directly between the elements. The inverted signal of slightly lower amplitude is the first reflection from the polystyrene-air interface. The second reflection, which is doubly inverted, lags the first reflection at a time interval equal to the delay between the direct signal and the first reflection. A low amplitude pulse follows each of these acoustic signals by about 4 μsec. These come from multiple reflections in the thin Kynar layer. The one associated with the direct signal is smaller than the others since it encounters two reflections at Kynar-film interfaces.

Figure 2 here

Figure 3 is a similar oscilloscope trace taken after assembly, with the neoprene front-face in place. Notice that the amplitude of the first reflection is decreased, as there is now a polystyrene-neoprene interface. The pulse following the first reflection is from the neoprene-air interface. In our application, this is the signal of interest since we are measuring the reflection coefficients between neoprene and paper board.

Figure 3 here

When the transducer is applied to a sample, a trace as shown in Fig. 4 is observed. In this case the sample is a sheet of paper board, and, since paper is very lossy in this frequency range, no signals from multiple reflections in the sample are observed. Some energy is, however, now coupled into the sample, and the front-face reflection is attenuated. The reflection coefficient at the neoprene-sample interface is minus the ratio of the front-face reflections in Fig. 4 and 3.

Figure 4 here

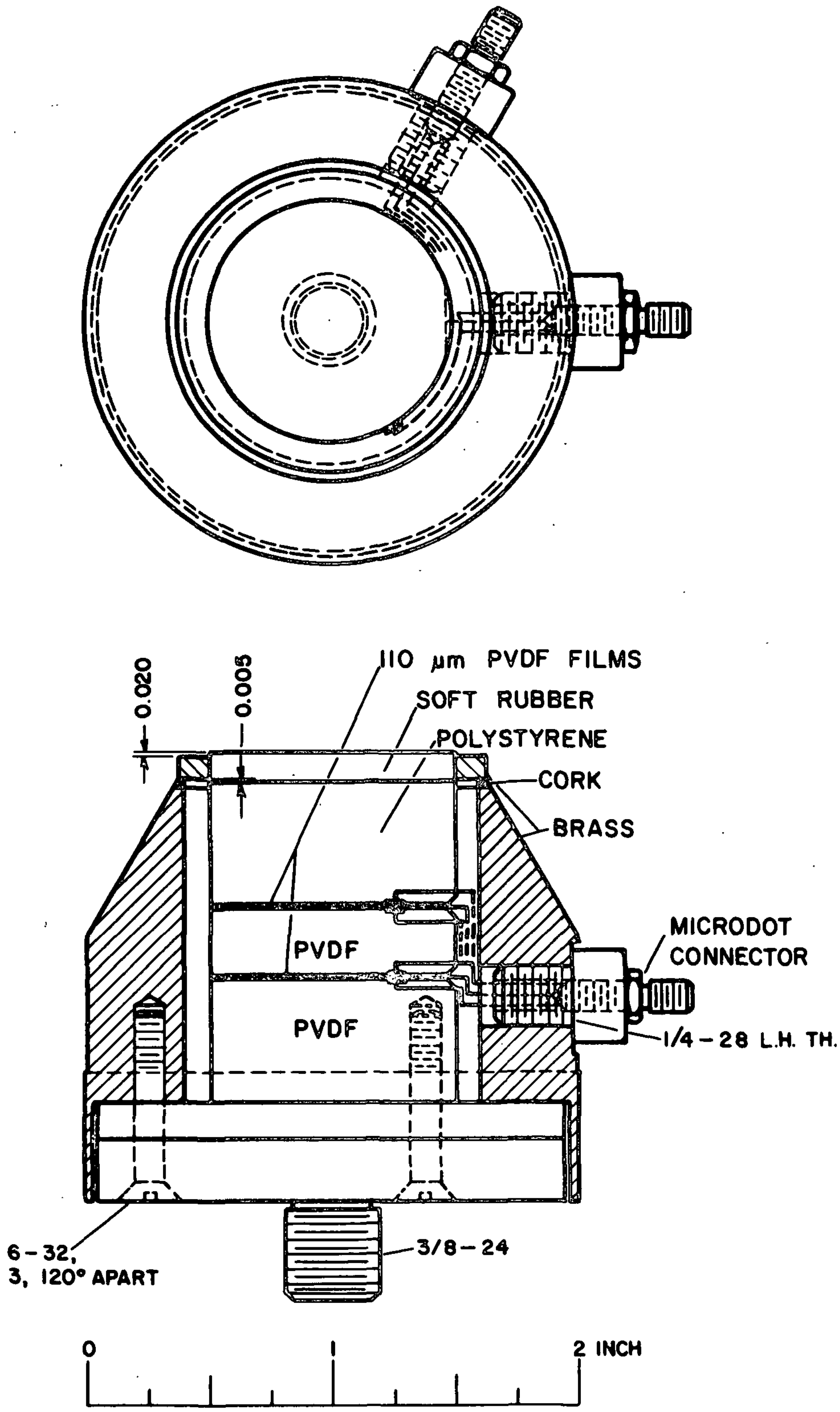
As demonstrated in the figures, the transducer is broad band, and delay line dimensions were chosen to isolate the front-face reflection. This provides an effective means to use pulse echo techniques to analyze sample interfaces without the special electrical circuitry used with standard pulse echo techniques.

REFERENCES

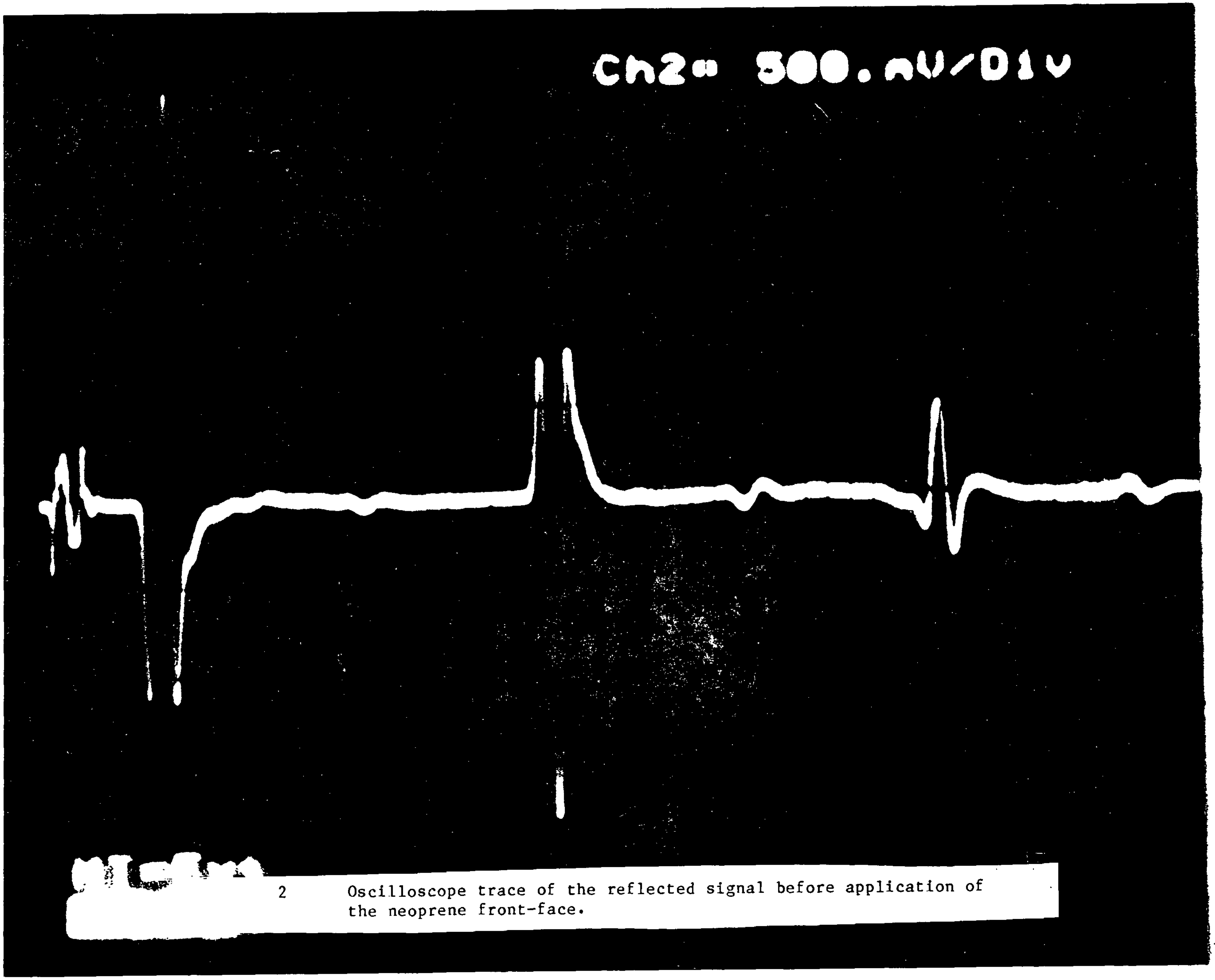
1. Truell, R., Elbaum, C., and Chick, B. Ultrasonic Methods in Solid State Physics, Academic Press, New York, Chapter 2, 1969.

2. Sung, K. Peizoelectric Multilayer Transducers for Ultrasonic Pulse Compression. Ultrasonics 22:61-68(1984).

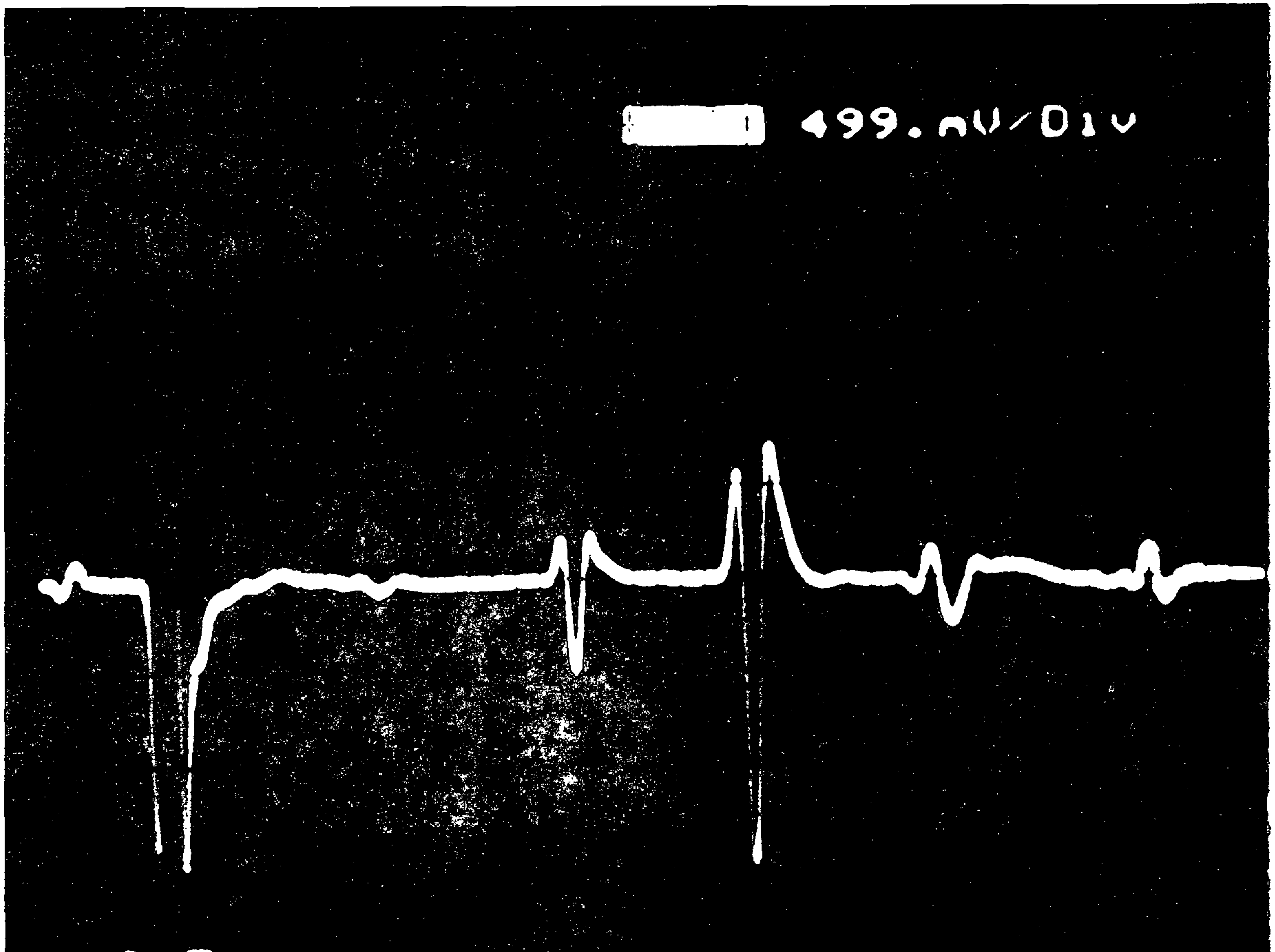
3. Habeger, C., Wink, W., and Van Zummeren, M. Using Neoprene-Faced PVDF Transducers to Couple Ultrasound into Solids. J. Acoust. Soc. Am. 84(4): 1388-1396(1988).



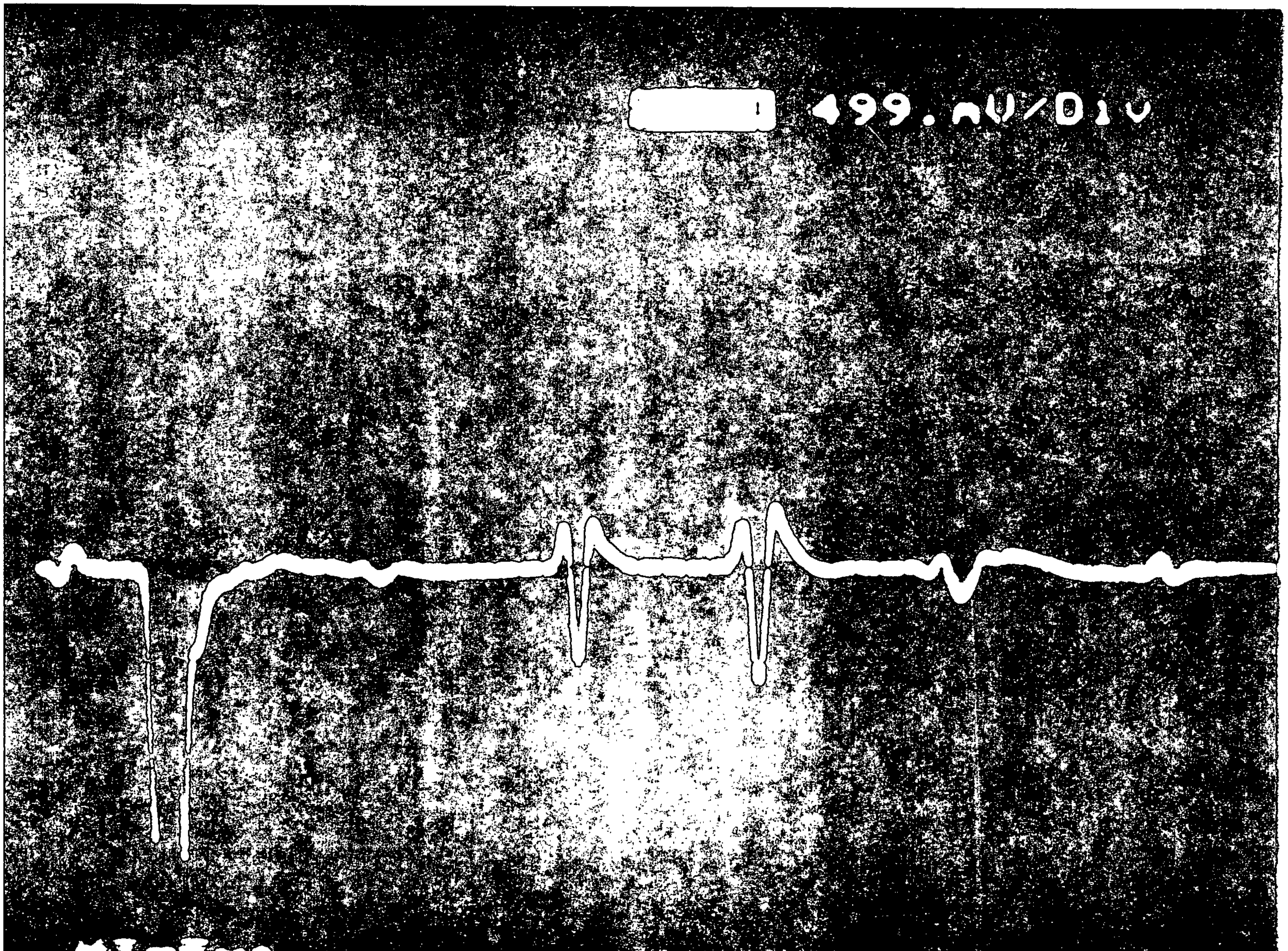

1 Mechanical drawing of the double element pulse echo transducer.




2 Oscilloscope trace of the reflected signal before application of the neoprene front-face.




3 Oscilloscope trace of the reflected signal for the completed transducer with no sample in place.




4 Oscilloscope trace of the reflected signal with a liner board sample coupled to the front-face.